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June, 2004

# BTeV's Staged Detector & Some Physics Reach Comparisons with LHCb

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# Some Significant Events in B Physics

| Year | Item | Theory Prediction | ~Value | # B's |
|---|---|---|---|---|
| 1983 | $\tau_b$ | Too small to be observed ~ < 0.1 ps | 1 ps | $2\times10^4$ |
| 1987 | $B^o$-$\overline{B}^o$ mixing | Too small to see (~ < 1%) as $m_{top}$ is believed to be ~30 GeV | 20% | $2\times10^5$ |
| 1987 | $V_{ub}/V_{cb}$ | No direct prediction | 0.1 | $2\times10^5$ |
| 1994 | $b\to s\gamma$ | $(2.8\pm0.8)\times10^{-4}$ | $2.3\times10^{-4}$ | $4\times10^6$ |
| 2001 | $\sin(2\beta)$ | No direct prediction, but consistent with other measurements | 3/4 | $10^7$ |

- B physics is an experimentally driven field with exciting discoveries, many not predicted.
- There is much much more physics to do.

# The Physics: General

*Mysteries*

*Solutions:*
*New Physics*

Dark Matter

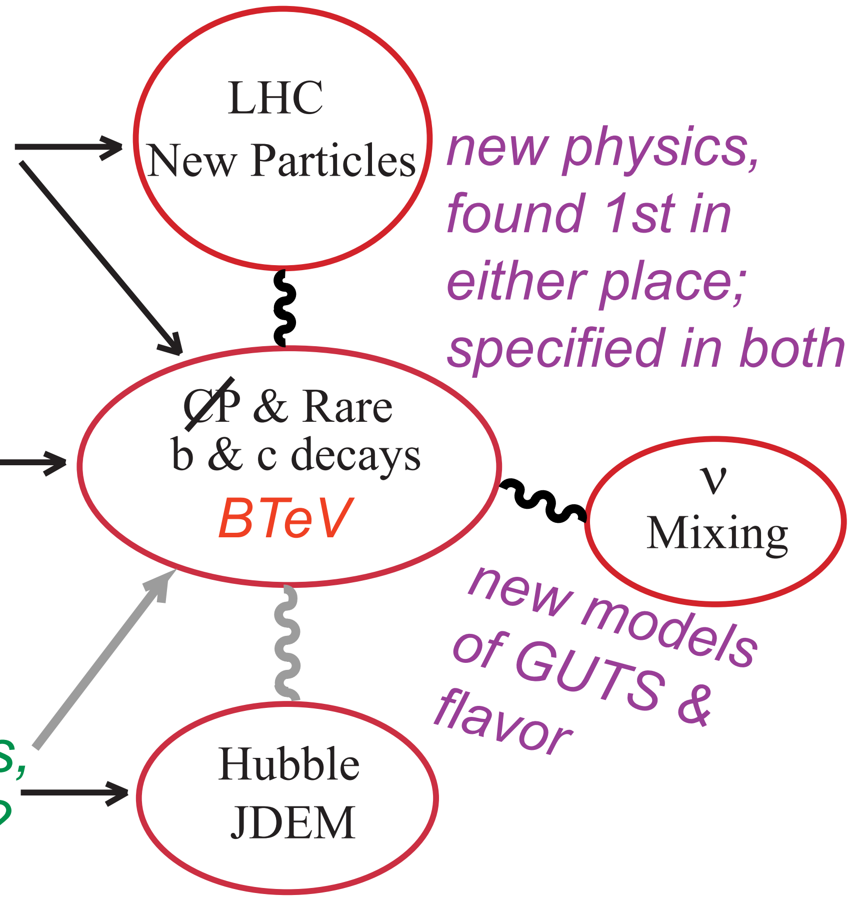
*new particles*

Dominance of Matter over Antimatter

*new source of CP violation*

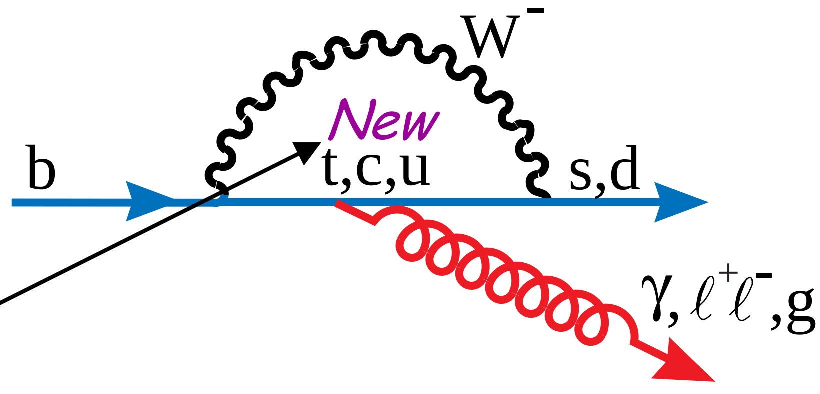
Dark Energy

*? new forces, dimensions?*



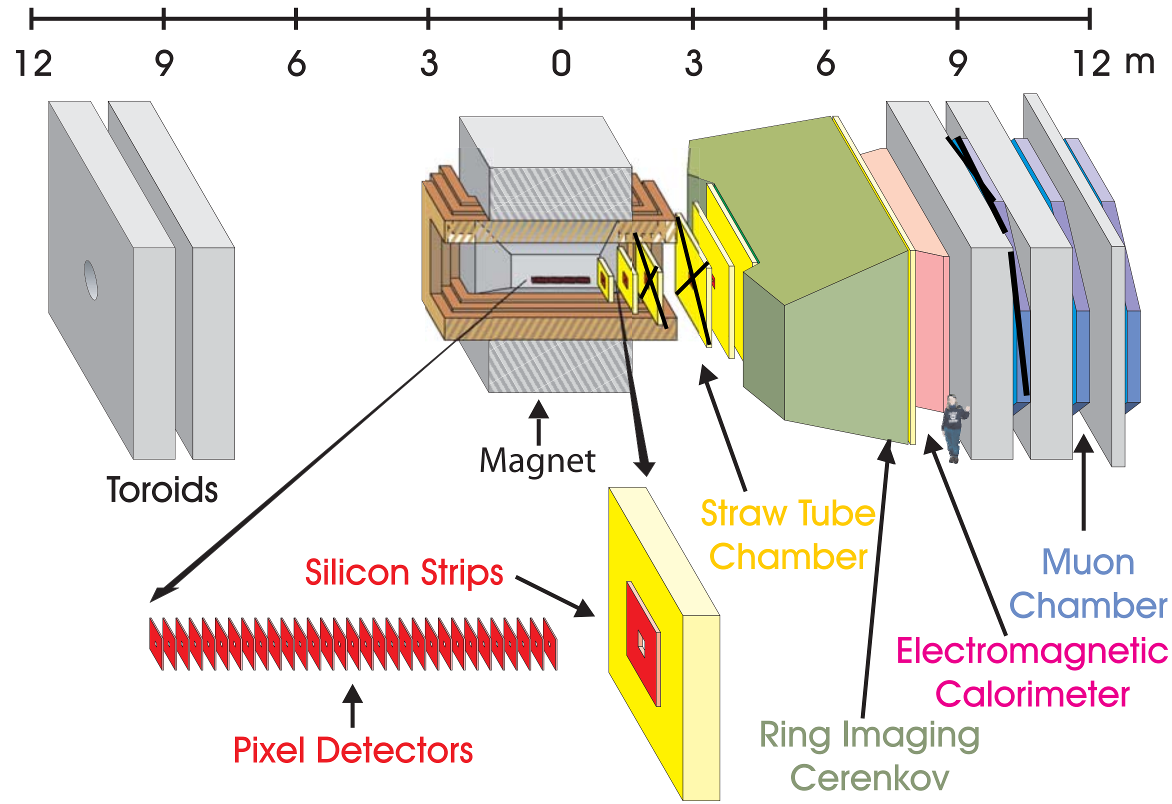
# The Physics: More Specific

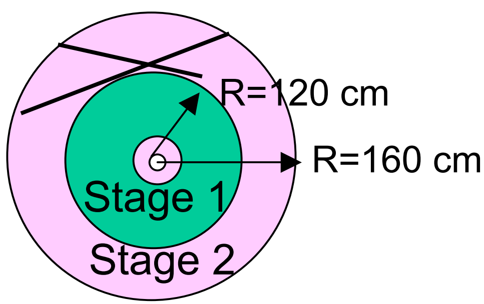
- CP Violation: Particles behave differently than antiparticles
  - Demonstrated in B decays by BaBar & Belle (one ∠ measured, β)
  - But there are 4 different angles to determine: α, β, γ, χ
  - Different incarnations of New Physics affect these angles in different ways. New Physics can show up as inconsistencies between/among CP measurements and other quantities.
- Rare Decays

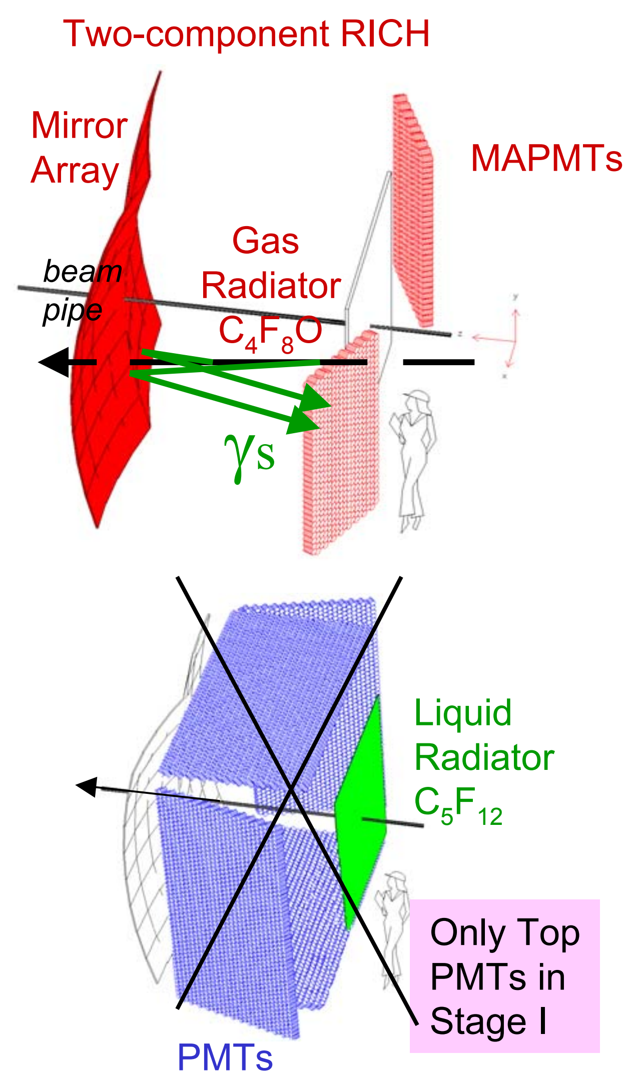



  - New Particles can appear in the loop & interfere – Phases of the new physics can be investigated

# BTeV's Staged Detector



# BTeV's Staged Detector - Details

- Stage I detector
  - 50% of EM cal - *we retain 60% of the rate on neutrals*
  - No liquid radiator system - *we retain 75% of flavor tagging rate*
  - Straw stations 3 & 4 are missing, as are Silicon stations 3, 4 & 7 - *no real physics effects, these are for redundancy*
  - No dimuon trigger & only 2 muon tracking stations - *no real effects, the dimuon trigger is a useful systematic check but can come later*
  - 50% of the trigger & DAQ highways - *no real effects on b's as there is alot of "head room" in the system and we can give up some charm initially*
- Stage II detector adds in all the missing components

# BTeV's Schedule

- Stage I starts August 1, 2009
- Then we run until July 1, 2010
  - Expect about 1 month to commission IR
  - Then its up to us to produce physics
- Summary of Stage 1
  - Estimate 6 months running time
  - Lab says that we will run 10 months a year and get 1.6 $fb^{-1}$
  - Thus this is a 1 $fb^{-1}$ run
  - We have 75% of our "normal" rate on all charged flavor tagged modes
  - We have 75% x 60% = 45% of our "normal" rate on flavor tagged modes with neutrals
- Some Commissioning done before on wire target or at end of stores and during the 1 month IR commissioning – *New IR has 2.5 x $\mathcal{L}$ than when BTeV was approved by P5!*

# LHC & LHCb's Schedule

- LHC running in steady state
  - In steady state mode, after a few years, they are scheduled to run 160 days a year for physics MINUS running for Heavy Ions - estimate 139 days on pp (see Collier, Proc. Chamonix XII, March 2003, CERN-AB-2003-008 ADM)
  - LHCb will start running at $2.8\text{x}10^{32}$; this gives using the formula in Collier 0.8 $fb^{-1}$ per calendar year
- LHCb initial running constraints
  - Initially plan to set β* 100 x ATLAS/CMS, to avoid multiple interactions/crossing as 1st runs will be with 1632 ns bunch spacing to avoid necessity of crossing angle (Here LHCb needs special set up to see collisions since they are displaced by 11.2 m from interaction region center)
  - First year will see limited running at 75 ns bunch spacing; LHCb will run at 2/3 $\text{x}10^{32}$ to avoid multiple int/xing. Second year will switch from 75 ns to 25 ns "when possible"

# LHCb's Schedule

- LHC schedule (LHCb-1)
  - Nominal: start April 1, 2007
  - We predict LHCb 2007 integrated luminosity to be 0.1 $fb^{-1}$
  - Since the 1st quarter of 2008 is still in the 1st year of tuning they will collect 0.6 $fb^{-1}$
  - They get the full 0.8 $fb^{-1}$ in 2009
- But - this schedule has no contingency

# LHCb's Schedule 2

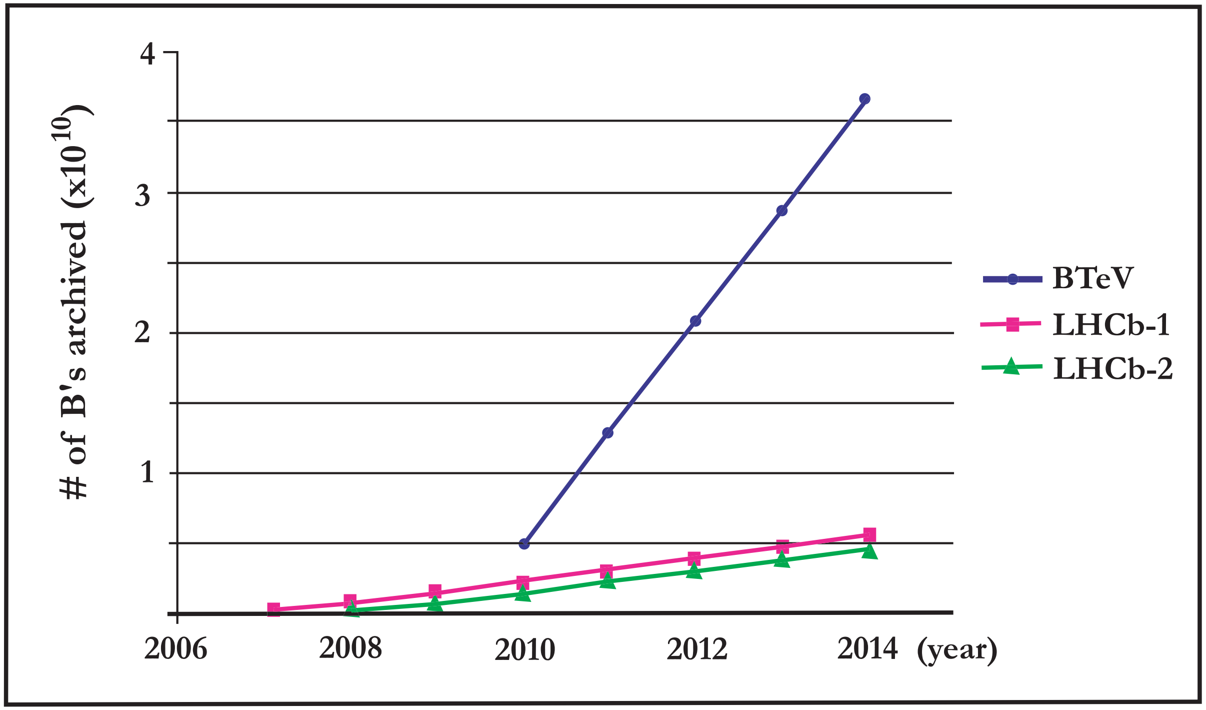
- Therefore we choose to set up an alternate schedule similar to the one that we have that has lots of float. A defensible schedule has ~ 12 months of float implying:
  - 0 $fb^{-1}$ in 2007
  - 0.1 $fb^{-1}$ in 2008
  - 0.6 $fb^{-1}$ in 2009
  - 0.8 $fb^{-1}$ in 2010 and beyond
- Neither for BTeV or LHCb is detector commissioning considered in what follows: we assume it will factor out of the comparisons
  - BTeV has some commissioning on wire target etc…
  - LHCb has limited accesses due to interference with ATLAS, CMS, etc..

# Yearly Integrated Luminosity Assumptions

$fb^{-1}$

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | Sum |
|---|---|---|---|---|---|---|---|---|---|
| LHCb-1 | 0.1 | 0.6 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 5.5 |
| LHCb-2 | | 0.1 | 0.6 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 4.7 |
| BTeV | | | | 1.5 | 1.6 | 1.6 | 1.6 | 1.6 | 7.9 |

# Comparison I - Total number of B's to "tape"

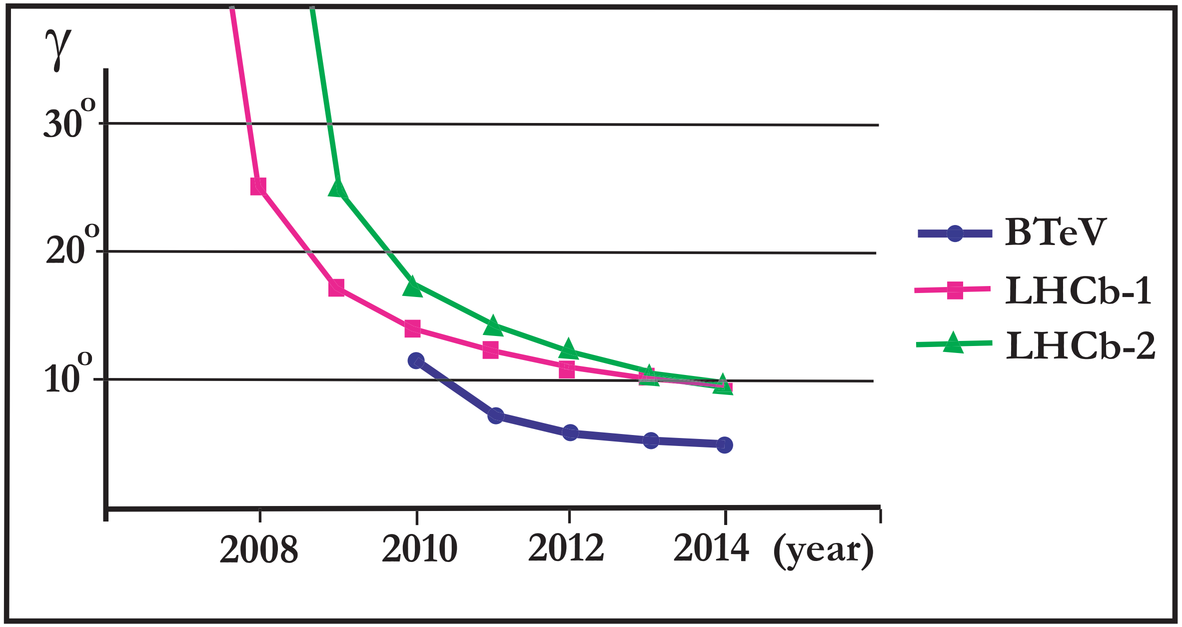



- For BTeV we take 1/2 the nominal rate in 2010 due to the staged detector
- BTeV is better by 5x from Trigger-DAQ & 2x from running time, giving a factor of 10 $b\bar{b}$'s to tape
- $e^+e^-$ at 1000 $fb^{-1}$ would have 0.1 $\times 10^{10}$ $b\bar{b}$'s

# Measuring $\gamma$ Using $B_s \rightarrow D_s K^-$

| | BTeV Stage I | BTeV Stage II | LHCb[10] |
|---|---|---|---|
| Yield (2 $fb^{-1}$) | 6,750 | 6,750 | 7,140 |
| S/B | 7 | 7 | >1 |
| $\epsilon \cdot D^2$ | 9.8% | 13% | 7.1% |
| Tagged yield (2 $fb^{-1}$) | 660 | 878 | 507 |
| Error in $\gamma$ for 2 $fb^{-1}$ | 9.4° | 8.4° | 14.5° |
| Error in $\gamma$/year (steady state) | | 10.9° | 26.5° |

From LHCb Light TDR



# Conclusion on Measuring $\gamma$ in $B_s \to D_s K^-$

- What is a meaningful measurement of a CP violating angle?
  - Example $B^o \to \phi K_s$ CP Asymmetry = $\sin 2\beta$ Babar: $0.47 \pm 0.34 \pm 0.07$, Belle: $-0.96 \pm 0.50 \pm 0.10$

    in $J/\psi\ K_s$ $\sin 2\beta = 0.74 \pm 0.05$. Thus both measurements are not definitive and both have an error in $\beta \sim 14^o$. Need $\delta\beta < 10^o$ or better!
- *Thus LHCb will not likely have a meaningful measurement of $\gamma$ in either of their turn on scenarios before BTeV, nor will they ever make a measurement as good as BTeV's*

# Measuring $\alpha$ using $B^o \to \rho\pi$

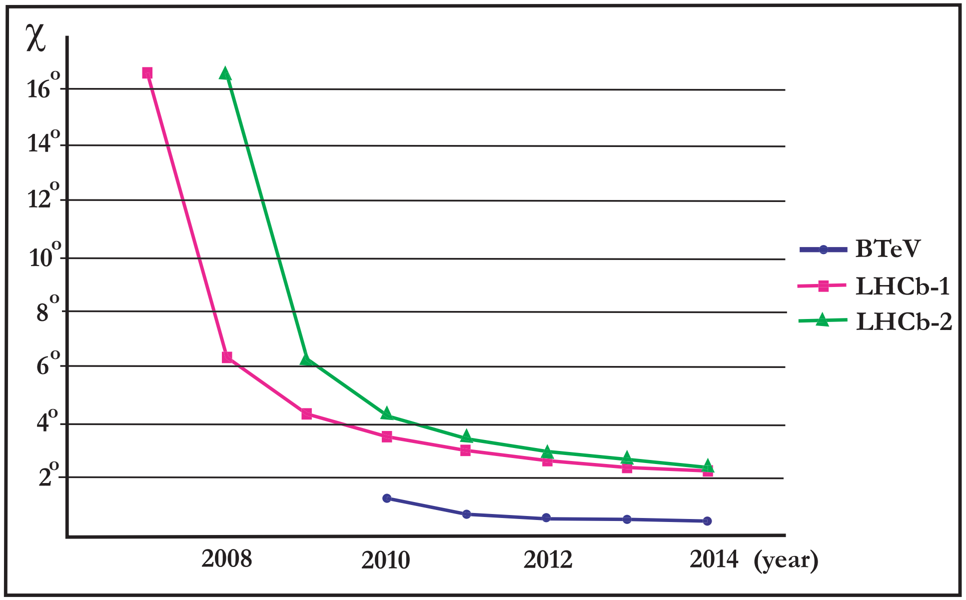
- LHCb
  - Shaslik-style Pb-scintillating fiber device, energy resolution $10\%/\sqrt{E} \oplus 1.5\%$ BTeV's is $1.7\%/\sqrt{E} \oplus 0.55\%$
  - The LHCb detector segmentation is 4x4 $cm^2$ up to 90 mr, 8x8 $cm^2$ to 160 mr and 16x16 $cm^2$ at larger angles. (The distance to the interaction point is 12.4 m.) Thus the segmentation is comparable to BTeV only in the inner region. (BTeV has 2.8 x 2.8 $cm^2$ crystals 7.4 m from the center of the interaction region.)
  - In 2 $fb^{-1}$ 7260 events, S/B <1/7.1, no estimate from LHCb of $\delta\alpha$, we find $11.7^o$ from these #'s compared to BTeV Stage I $6.3^o$
- *Since LHCb will accumulate only half the integrated luminosity of BTeV per year, it is clear that they will not be able to make a definitive measurement of $\alpha$, in fact, it is likely that they will not be able to make one at all, not surprising because of the poor energy resolution and segmentation of their calorimeter.*

# Measuring $\chi$ in $B_s$ decays

- Modes
  - BTeV uses CP eigenstates: $J/\psi\ \eta^{(\prime)}$
  - LHCb uses $J/\psi\ \phi$, VV mode so they must do a transversity analysis
- CDF & D0 get 1 $J/\psi\ \phi$ each per $pb^{-1}$ $\Rightarrow \delta\chi \sim 13^o$ in Run II, **if** $B_s$ mixing is also measured (sets a floor on $\int L$)

| | BTeV Stage I | BTeV Stage II | LHCb[10] |
|---|---|---|---|
| Yield (2 $fb^{-1}$) | 6,800 | 11,340 | 100,000 |
| S/B | 20 | 20 | >3 |
| $\epsilon \cdot D^2$ | 9.8% | 13% | 5.5% |
| Tagged yield (2 $fb^{-1}$) | 660 | 1474 | 5500 |
| Error in $\chi$ for 2 $fb^{-1}$ | 1.1° | 0.7° | 3.7° |
| Error in $\chi$/year (steady state) | | 0.9° | 5.9° |

# Conclusions on $\chi$




LHCb will have a chance in 2009 of making a significant measurement of $\chi$, if it is in excess of ~20° and they collect sufficient integrated luminosity to improve over the combined CDF & DO measurement. At the end of 2010 BTeV will have the best measurement of $\chi$ and the error will eventually be less than 0.5°.

*Thus BTeV has the best chance of making a significant measurement if new physics is present and is the only detector that can measure $\chi$ if new physics doesn't make a very large contribution.*

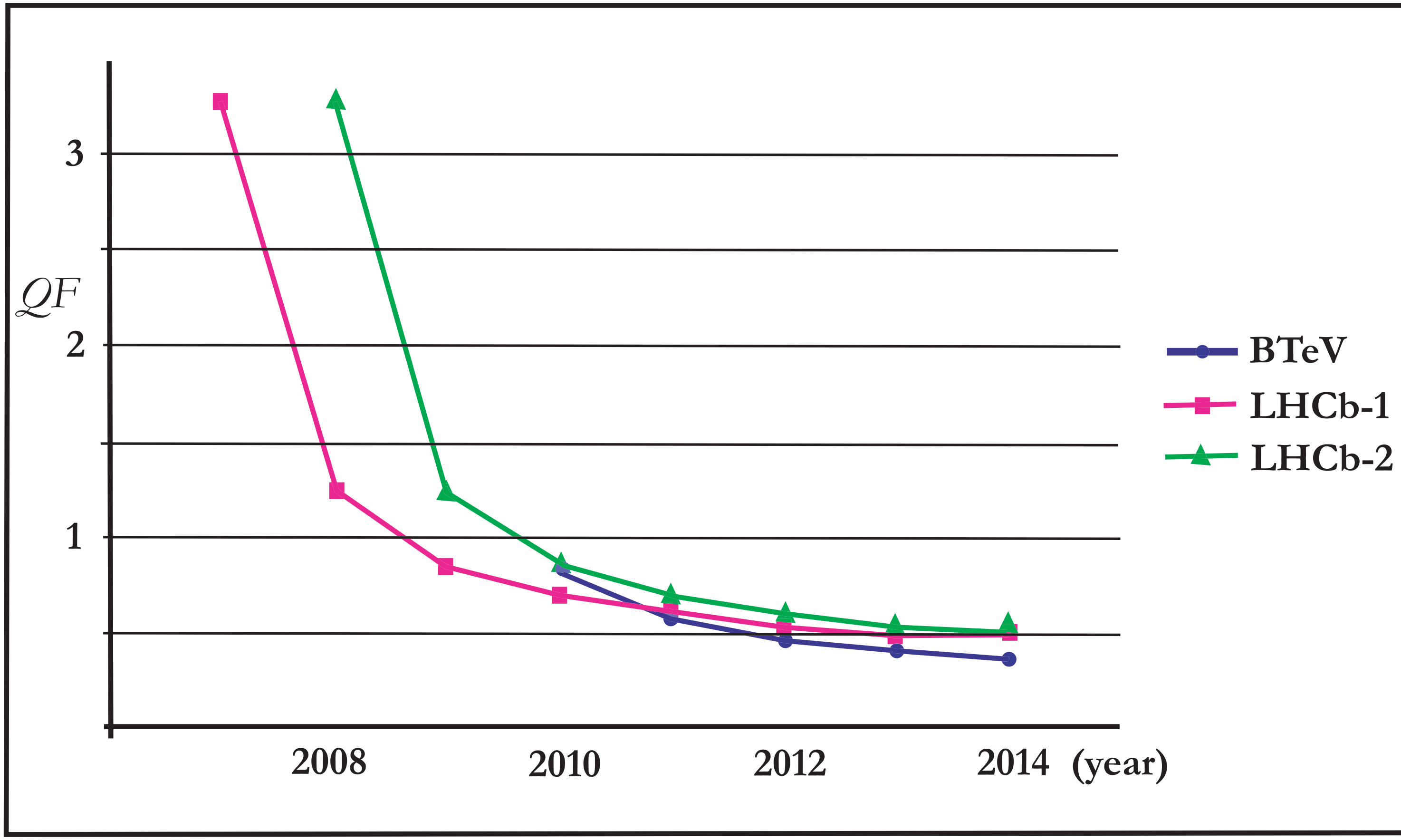
# The Rare Decay $B^o \rightarrow K^{*o}\mu^+\mu^-$

- Want to measure the polarization
- No flavor tagging here
- Define $QF = \sqrt{1000/(\#\,of\ events)} \times \sqrt{(S+B)/S}$

| | BTeV | LHCb[10] |
|---|---|---|
| Yield (2 $\text{fb}^{-1}$) | 2277 | 5546 |
| S/B | 7 | >0.5 |
| $QF$ | 0.71 | 0.74 |
| Yield in 1 calendar year | 1700 | 1660 |
| $QF$/year steady state | 0.63 | 1.34 |

- BTeV eventually overtakes LHCb

# Time dependence of $B^o \rightarrow K^{*o}\mu^+\mu^-$




- This is LHCb's best case: They trigger on dimuons, there is no flavor tagging, and yet BTeV eventually has smaller errors

# Conclusions

- The LHC turn on will be a long process by their own projections. Latest information (CMS May review), it will not start before August 2007
- LHCb will have trouble dealing with initial 75 ns running
- LHCb may get lucky and measure something "easy" like $B_s$ mixing, if CDF & D0 don't do it but they will have to overcome what both CDF & D0 do with Bs & what the B factories do with $B^o$ & $B^-$
- In the slightly longer term, BTeV will dominate measurements of $\alpha$, $\gamma$, & $\chi$
- After 2010 BTeV's physics reach will dominate in all areas